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Pre-planned anesthetic strategy for a penetrating ballistic injury involving the aortic root and tracheal carina: a case report

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Case Report

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Abstract

Background: Penetrating thoracic trauma simultaneously involving the great vessels and the central airway is rare and poses exceptional anesthetic challenges. Reports detailing the anesthetic management of retained metallic fragments lodged adjacent to both the aortic root and the tracheal carina are scarce. We present such a case, managed without cardiopulmonary bypass, together with a review of comparable published cases.

Case presentation: A 36-year-old woman sustained a penetrating right anterior chest wall injury from a shattered metal grinding wheel. Contrast-enhanced computed tomography localized two irregular metallic fragments at the aortic transverse sinus and embedded in the tracheal carina. After multidisciplinary planning, anesthesia was induced with a rapid-sequence technique using hemodynamically stable agents (remimazolam, etomidate, sufentanil, and mivacurium). A left-sided double-lumen tube was placed on the first attempt under direct laryngoscopy, and one-lung ventilation with zero positive end-expiratory pressure was maintained for 75 minutes while cardiac and thoracic surgical teams sequentially removed both fragments. Central venous pressure-guided restrictive fluid management was applied; neither cardiopulmonary bypass nor vasoactive support was required. The patient was extubated 12 hours postoperatively and discharged on postoperative day 12 after successful treatment of postoperative pneumonia.

Conclusions: A pre-planned anesthetic strategy combining rapid-sequence induction with hemodynamically neutral agents, lung isolation with protective zero-PEEP ventilation, and central venous pressure-guided restrictive resuscitation can support combined great-vessel and carinal foreign-body surgery without cardiopulmonary bypass. In this case, multidisciplinary rehearsal, contrast-enhanced CT-based planning, and readiness for rapid escalation were central to the favorable outcome.

Background

Penetrating thoracic trauma accounts for approximately 20–30% of trauma-related deaths, and injuries involving the great vessels or the central airway constitute the most lethal subset [1]. The aortic root, pulmonary artery, superior vena cava, and tracheobronchial tree are packed within a confined mediastinal space, so a high-velocity penetrating object can compromise the circulatory and respiratory systems simultaneously. When metallic foreign bodies remain lodged in this region, the anesthesiologist faces three concurrent problems: maintaining hemodynamic stability despite possible occult vascular injury, securing an airway that may be distorted by hematoma or foreign material, and achieving lung isolation for surgical exposure without dislodging the fragments or worsening the injuries.

Management of such cases requires a carefully planned anesthetic strategy that integrates damage control resuscitation [2], rapid sequence induction (RSI) in the hemodynamically tenuous patient, and protective one-lung ventilation (OLV) in the setting of acute lung injury. The coexistence of fragments adjacent to the aortic root and the tracheal carina is particularly rare, and published reports addressing the anesthetic — rather than purely surgical — management of this combined pathology are scarce.

We present a case of metal-grinding-wheel shrapnel injury with fragments lodged at the aortic transverse sinus and the tracheal carina. We detail the preoperative assessment, anesthetic planning, intraoperative management, and postoperative course, and review comparable published cases. Our aim is to offer a practical anesthetic framework for similar high-risk penetrating cardiothoracic trauma. This case is reported in accordance with the CARE (CAse REport) guidelines; the completed CARE checklist is provided as Additional file 1.

Case presentation

Patient information and clinical findings

A 36-year-old woman (weight 75 kg, height 165 cm, body mass index 27.5 kg/m²) was admitted to the emergency department at 21:09 on 4 March 2026 after sustaining a penetrating injury to the right anterior chest from a shattered metal grinding wheel. The mechanism involved high-velocity ejection of metallic shrapnel. She had no relevant past medical, family, or psychosocial history and took no regular medications. On arrival she was conscious and oriented (Glasgow Coma Scale 15) but complained of chest pain and dyspnea. Vital signs on admission are summarized in Table 1.

Table 1
Vital signs on emergency department admission.

Parameter	Value	Notes
Temperature	36.5°C	Normothermic
Heart rate	100 beats/min	Tachycardic
Respiratory rate	36 breaths/min	Tachypneic
Blood pressure	125/75 mmHg	Compensated
SpO_2 (room air)	94%	Mild hypoxemia
Glasgow Coma Scale	15	Intact

NEWS = National Early Warning Score; SpO_2 = peripheral oxygen saturation.

Physical examination revealed a 2-cm penetrating wound on the right anterior chest wall in the parasternal region, with minimal active bleeding and slight serosanguinous drainage. Auscultation demonstrated diminished breath sounds over the right upper lung field. Chest percussion revealed dullness over the right upper lobe.

Emergency non-contrast chest computed tomography (CT) demonstrated: (1) soft-tissue swelling and subcutaneous emphysema of the right anterior chest wall, with discontinuity of the right second anterior costal cartilage; (2) a small right pneumothorax with arc-shaped pleural effusion, patchy increased density in the anterior mediastinum, and mediastinal emphysema; (3) scattered patchy ground-glass

opacities in the right lung and left lower lobe, most prominent in the right upper lobe; and (4) metallic foreign-body shadows with streak artifacts adjacent to the tracheal carina and right main bronchus, with patent trachea and segmental bronchi (Fig. 1). Contrast-enhanced CT further localized fragment 1 at the aortic transverse sinus, immediately adjacent to the ascending aorta and main pulmonary artery, and fragment 2 embedded in the tracheal carina slightly right of midline; a three-dimensional volume-rendered reconstruction, generated postoperatively on 20 September 2026 from the preoperative contrast-enhanced CT dataset, illustrates these spatial relationships (Fig. 2). The irregular shape of both fragments and their intimate relationship to the great vessels raised immediate concern for vascular laceration and catastrophic hemorrhage; retained foreign bodies also posed a substantial risk of secondary infection.

Preoperative risk stratification yielded a modified National Early Warning Score (NEWS) of 2 and a Caprini venous thromboembolism risk score of 3 (moderate risk). Given the extreme proximity of the fragments to the aorta, pulmonary artery, and superior vena cava, urgent surgical intervention was deemed necessary. After the family was counseled regarding the life-threatening nature of the injury, a multidisciplinary preoperative discussion was convened involving cardiac surgery, thoracic surgery, anesthesiology, and the intensive care unit (ICU) to establish the surgical sequence and contingency plans for massive hemorrhage, cardiopulmonary bypass (CPB), and loss of airway control. The key events of the episode of care are summarized as a timeline in Table 2.

Table 2
Timeline of the episode of care (CARE item 7).

Date / time	Event
4 March, 21:09	Emergency department admission; two 18-G peripheral lines; 500 mL colloid
4 March, shortly after admission	Non-contrast then contrast-enhanced chest CT with 3D reconstruction; fragments localized
4–5 March	Multidisciplinary discussion (cardiac surgery, thoracic surgery, anesthesiology, ICU)
5 March, 00:25	Arrival in operating room; standard monitoring; preoxygenation
5 March, 00:57	RSI; 37-Fr left DLT placed at first attempt; fiberoptic confirmation
5 March, 01:07	Right radial arterial line (ultrasound-guided)
5 March, 01:12	7-Fr triple-lumen central venous catheter
5 March, 01:40	One-lung ventilation started
5 March, 01:42	Heparin 5,000 U iv; fragment 1 removed without CPB
5 March, 02:55	OLV ended; fragment 2 removed; carinal and parenchymal repair
5 March, 04:00	Surgery concluded; 04:10 departure from operating room
Postop. 12 h	Extubation in ICU
Postop. day 2	Fever; right lower-lobe pneumonia; antibiotics started
Postop. day 5	Discharged from ICU
Postop. day 7	Chest tube removed
Postop. day 12	Hospital discharge
Postop. 1 month	Outpatient follow-up: asymptomatic; normal spirometry

Anesthetic management

Preoperative assessment and planning. The preoperative anesthetic evaluation focused on three core concerns: (1) hemodynamic instability from concealed vascular injury; (2) airway compromise from tracheal or carinal laceration; and (3) the need for lung isolation to provide surgical access to both the mediastinal great vessels and the distal trachea. The patient was classified as American Society of Anesthesiologists physical status IIE (emergency case).

Given the risk of cardiovascular collapse on induction, a damage control resuscitation strategy was adopted. Two large-bore (18-gauge) peripheral intravenous lines were established in the emergency department, and 500 mL of colloid solution was infused before transfer. Cross-matched blood products

(4 units of packed red blood cells and 2 units of fresh frozen plasma) were made immediately available in the operating room, and a cell-salvage system was prepared but ultimately not used.

Airway planning prioritized placement of a left-sided double-lumen endobronchial tube (DLT, 37 Fr), both to secure the airway distal to any potential tracheal injury and to enable OLV. A high-frequency jet ventilation (HFJV) system was kept on standby in the event of tracheal disruption or loss of conventional airway control.

Induction and airway management. Standard monitoring (electrocardiography, pulse oximetry, noninvasive blood pressure, capnography) was applied, and preoxygenation with 100% oxygen was performed for 3 minutes. RSI was performed after premedication with promethazine 6.25 mg, flurbiprofen axetil 50 mg, penehyclidine 1 mg, and tropisetron 5 mg. Induction consisted of remimazolam 8 mg, etomidate 14 mg, sufentanil 50 mcg, and mivacurium 20 mg intravenously. After intubation, anesthesia was maintained with sevoflurane 1.3% and a continuous mivacurium infusion (10 mL/h); cisatracurium 14 mg was added intraoperatively.

We chose the etomidate–remimazolam combination for its hemodynamic profile: etomidate provides rapid hypnotic onset with minimal cardiovascular depression, while remimazolam is an ultrashort-acting benzodiazepine metabolized by tissue esterases and reversible with flumazenil [3, 4]. Sufentanil (approximately 0.67 mcg/kg) provided potent analgesia at a dose selected to avoid histamine-mediated hypotension. Mivacurium, a short-acting non-depolarizing blocker, was chosen to permit early neurological assessment; cisatracurium, eliminated by Hofmann degradation, was used for intraoperative supplementation.

Direct laryngoscopy (Macintosh blade, size 3) revealed a Cormack–Lehane grade I view, and the 37-Fr left-sided DLT was inserted successfully on the first attempt at 00:57. Fiberoptic bronchoscopy confirmed correct positioning — the bronchial cuff seated in the left mainstem bronchus and the tracheal cuff proximal to the carina — and showed no tracheal laceration or false passage; importantly, the carinal fragment had not penetrated the tracheal lumen (Fig. 5, Additional file 2).

Monitoring and vascular access. At 01:07, a 20-gauge arterial catheter was placed in the right radial artery under ultrasound guidance, and at 01:12 a 7-Fr triple-lumen central venous catheter was inserted for central venous pressure (CVP) monitoring and rapid infusion. The initial CVP was 10 mmHg, indicating adequate but not excessive preload after emergency-department resuscitation.

Ventilation strategy. Volume-control ventilation was set at tidal volume 450 mL (approximately 7.9 mL/kg predicted body weight), respiratory rate 14/min, inspiratory-to-expiratory ratio 1:2, and fraction of inspired oxygen (FiO_2) 0.65. Positive end-expiratory pressure (PEEP) was withheld (0 cmH_2O) to minimize intrathoracic pressure and reduce the theoretical risk of fragment dislodgement or worsening of occult vascular injury. OLV was initiated at 01:40 and maintained for 75 minutes (until 02:55) with unchanged settings; oxygen saturation remained above 95%, end-tidal CO_2 between 35 and 42 mmHg,

and peak airway pressure below 20 cmH_2O (Table 3). No recruitment maneuvers were performed. HFJV remained on standby and was not required.

Table 3
Ventilation parameters during surgery.

Phase	Time	VT (mL)	RR (/min)	FiO_2 (%)	PEEP (cmH_2O)	Ppeak (cmH_2O)
Two-lung ventilation	00:57–01:40	450	14	65	0	13–15
One-lung ventilation	01:40–02:55	450	14	65	0	15–20
Two-lung ventilation	02:55–end	450	14	65	0	13–15

VT = tidal volume; RR = respiratory rate; FiO_2 = fraction of inspired oxygen; PEEP = positive end-expiratory pressure; Ppeak = peak airway pressure.

Intraoperative course and hemodynamic management. The cardiac surgical team first addressed fragment 1 at the aortic transverse sinus with the perfusion team on standby for emergent CPB; heparin 5,000 units was administered intravenously at 01:42. The fragment was extracted without aortic cross-clamping or CPB because the metal had not fully penetrated the aortic wall. The thoracic surgical team then addressed fragment 2, which had entered at approximately the level of the third anterior rib, traversed the anterior segment of the right upper lobe, passed anterior to the right main pulmonary artery below the confluence of the superior vena cava and azygos vein, and embedded in the carina just right of midline. Because the fragment had not penetrated the tracheal lumen, formal carinal reconstruction was not required; carinal and pulmonary parenchymal repair was performed, followed by chest-wall debridement and closure.

Mean arterial pressure was maintained between 65 and 85 mmHg throughout. CVP rose to 13 mmHg during OLV and fell to 4 mmHg by the end of surgery (Table 4). Total intraoperative fluid administration was 800 mL of crystalloid and colloid solution in addition to the 500 mL given in the emergency department; estimated blood loss was 200 mL; no blood products were transfused. Norepinephrine had been prepared but no vasoactive or inotropic agent was administered. Surgery concluded at 04:00, anesthesia ended at 04:05, and the patient left the operating room at 04:10 (total operative time approximately 2 hours 49 minutes).

Table 4
Hemodynamic and fluid management timeline.

Time point	CVP (mmHg)	MAP (mmHg)	Cumulative fluid (mL)	Blood loss (mL)
Admission to ER	—	—	500 (colloid)	Minimal
Post-induction	10	72	500	—
During OLV	13	78	700	100
End of surgery	4	75	1300	200

CVP = central venous pressure; MAP = mean arterial pressure; ER = emergency room; OLV = one-lung ventilation.

Follow-up and outcomes

The patient was transferred to the ICU intubated, sedated with propofol and remifentanil, with an underwater-seal chest drain in place. Serial chest radiographs showed gradual resolution of the pneumothorax and mediastinal emphysema. Extubation was performed 12 hours postoperatively after confirmation of adequate oxygenation (SpO_2 > 96% on FiO_2 0.40), hemodynamic stability without vasoactive support, intact airway reflexes, minimal chest-tube output (< 50 mL/h), and a chest radiograph without expanding pneumothorax or significant atelectasis.

On postoperative day 2 the patient developed fever (38.5°C) and leukocytosis (14.2 × 10^9/L); chest CT showed right lower-lobe consolidation consistent with aspiration pneumonia — an adverse and unanticipated event. Empiric piperacillin–tazobactam was initiated and de-escalated to ceftriaxone after sputum culture grew Streptococcus pneumoniae; the pneumonia resolved after 7 days of targeted therapy. She was discharged from the ICU on postoperative day 5, the chest tube was removed on day 7, and she left the hospital on day 12 in good condition. At 1-month outpatient follow-up she remained asymptomatic, with normal spirometry and a healed chest wound.

Patient perspective. "The moment the machine exploded, I thought I was going to die. Breathing was very difficult at the beginning. The anesthesiologist told my family that I might not survive. The moment I woke up in the intensive care unit, although I was in pain, I knew I was not going to die."

Discussion

Several aspects of the anesthetic management deserve comment. Preoperative multidisciplinary planning underpinned the entire episode: the anesthetic, cardiac surgical, thoracic surgical, and ICU teams held a structured huddle to fix the surgical sequence, anticipate the possible need for CPB, and agree on contingency plans for massive hemorrhage and airway loss. For injuries that span multiple anatomical zones and specialties, this coordination is the foundation of patient safety.

The induction regimen was selected with cardiovascular collapse in mind. The remimazolam–etomidate combination is a reasonable option for RSI in trauma patients at risk of hemodynamic deterioration. Etomidate preserves vascular tone and myocardial contractility, and single-dose etomidate has not been consistently associated with excess mortality in acutely ill patients requiring rapid-sequence intubation [3, 5]. Remimazolam adds amnesia and anxiolysis with minimal cardiovascular depression and the security of flumazenil reversibility [4]. Our patient required no vasoactive support at any point, which is consistent with the hemodynamic neutrality of this regimen, although causality cannot be established from a single case.

We chose a DLT over a single-lumen tube with a bronchial blocker because it provides secure lung isolation while preserving the ability to convert rapidly to independent lung ventilation should the airway be disrupted [6]. Bronchoscopic confirmation of tube position doubled as a diagnostic airway survey, and the finding that the carinal fragment had not breached the tracheal lumen immediately de-escalated both the surgical and anesthetic plans.

The zero-PEEP strategy is arguably the most debatable element of our management. Protective ventilation with low tidal volumes is standard for thoracic surgery and acute lung injury [7]; however, PEEP increases intrathoracic pressure, reduces venous return, and in the presence of sharp retained fragments adjacent to the great vessels carries a theoretical risk of fragment migration and vascular injury. We accepted the trade-off of zero PEEP with modest tidal volumes and an FiO_2 of 0.65, which maintained adequate oxygenation throughout 75 minutes of OLV. This approach succeeded in a patient with relatively preserved baseline lung function and limited pulmonary contusion; in patients with more severe contusion or refractory hypoxemia, carefully titrated PEEP — or differential lung ventilation — may still be necessary, and our strategy should not be generalized uncritically.

Fluid management followed damage control resuscitation principles [2, 8], with CVP guiding a restrictive approach. We interpreted CVP trends rather than absolute values: the rise to 13 mmHg during OLV reflected increased intrathoracic pressure rather than volume overload, and the fall to 4 mmHg at the end of surgery accompanied stable arterial pressure, suggesting successful redistribution and resolution of the stress response. CVP is a static and imperfect surrogate of preload responsiveness, but in this setting it provided a continuous, low-risk trend that complemented direct arterial pressure monitoring.

Comparison with published cases. Reports of retained intrathoracic metallic foreign bodies have focused predominantly on surgical strategy, with limited attention to anesthetic planning. Zhao et al. described a worker impaled by a falling T-shaped metallic bar traversing the right thorax, managed by direct extraction under general anesthesia with surgical standby [9]. Chen et al. reported a grinding-machine fragment retained within the right subclavian vein, removed under local anesthesia with proximal and distal vascular control [10]. More recently, Lurin et al. reported a combat shrapnel fragment retained in the anterior superior mediastinum, removed thoracoscopically under OLV with a double-lumen tube using magnetic instruments [11]. In none of these reports were fragments simultaneously adjacent to the aortic root and the tracheal carina, and none described the anesthetic management of

sequential cardiothoracic and airway surgery. To our knowledge, no previous report has detailed a complete anesthetic plan — hemodynamically neutral RSI, first-attempt DLT placement with bronchoscopic airway survey, zero-PEEP protective OLV, and CVP-guided fluid restriction — supporting two-team mediastinal surgery without CPB in this setting.

Strengths and limitations. The strengths of this report include complete pre-, intra-, and post-operative data, contrast-enhanced CT-based planning, and a prespecified multidisciplinary strategy. Several limitations must be acknowledged. This is a single case, and the favorable outcome partly reflects favorable anatomy — the fragments had not breached the aortic wall or tracheal lumen — which cannot be predicted preoperatively. Intraoperative arterial blood gas analyses were not obtained because the clinical course was stable, limiting objective documentation of oxygenation and ventilation during OLV. The zero-PEEP strategy, as discussed above, may not generalize to patients with more severe lung injury. Finally, follow-up extended to only one month, so late complications such as retained-fragment infection or airway stenosis cannot be excluded, although both fragments were removed in their entirety.

Take-away lessons. For anesthesiologists facing penetrating mediastinal trauma with retained fragments near the great vessels and airway: (1) rehearse the plan as a multidisciplinary team, including CPB standby, before induction; (2) induce with hemodynamically neutral agents and have vasopressors prepared but not necessarily running; (3) use the intubation bronchoscopy as a diagnostic airway survey, not merely a positioning check; (4) weigh the physiological benefits of PEEP against the mechanical risk it may pose to retained sharp fragments; and (5) guide fluids by trends in CVP and arterial pressure rather than fixed targets.

Conclusions

Penetrating thoracic trauma involving the aortic root and tracheal carina demands careful preoperative planning, judicious pharmacologic management, and an adaptive intraoperative strategy. This case shows that rapid-sequence induction with hemodynamically neutral agents, lung isolation with zero-PEEP protective ventilation, and CVP-guided restrictive resuscitation can support complex cardiothoracic foreign-body surgery without cardiopulmonary bypass or vasoactive support. Multidisciplinary coordination, contrast-enhanced CT-based planning, and preparation for rapid escalation contributed to the favorable outcome.

Abbreviations

ASA
American Society of Anesthesiologists
CARE
CAse REport guidelines
CPB
cardiopulmonary bypass

CT
computed tomography
CVP
central venous pressure
DLT
double-lumen endobronchial tube
FiO_2
fraction of inspired oxygen
HFJV
high-frequency jet ventilation
ICU
intensive care unit
NEWS
National Early Warning Score
OLV
one-lung ventilation
PEEP
positive end-expiratory pressure
RSI
rapid sequence induction
SpO_2
peripheral oxygen saturation.

Declarations

Ethics approval and consent to participate:

This case report was approved by the Ethics Committee of Gansu Provincial Hospital (approval number 2026 – 852, approved on 21 September 2026). Written informed consent was obtained from the patient for participation and publication.

Consent for publication:

Written informed consent was obtained from the patient for publication of this case report and all accompanying images, including the three-dimensional reconstructions. A copy of the signed consent form is available to the Editor on request.

Competing interests:

The authors declare that they have no competing interests.

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Author Contribution

WFG managed the patient, collected the clinical data, and drafted the manuscript. RFL conceived the report, supervised the anesthetic management, and critically revised the manuscript for important intellectual content. All authors read and approved the final manuscript. [Authors: please confirm this division of contributions before submission]

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Clinical trial number: not applicable.

Availability of data and materials:

All data generated or analyzed during this study are included in this published article; further details are available from the corresponding author on reasonable request.

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Figures



Figure 1

Preoperative chest computed tomography. (A) Axial, (B) coronal, and (C) sagittal reconstructions showing the metallic fragments (arrows) with streak artifact embedded at the tracheal carina slightly right of midline; note right upper-lobe contusion, right pneumothorax, and mediastinal and subcutaneous emphysema. Scale bar = 10 cm.

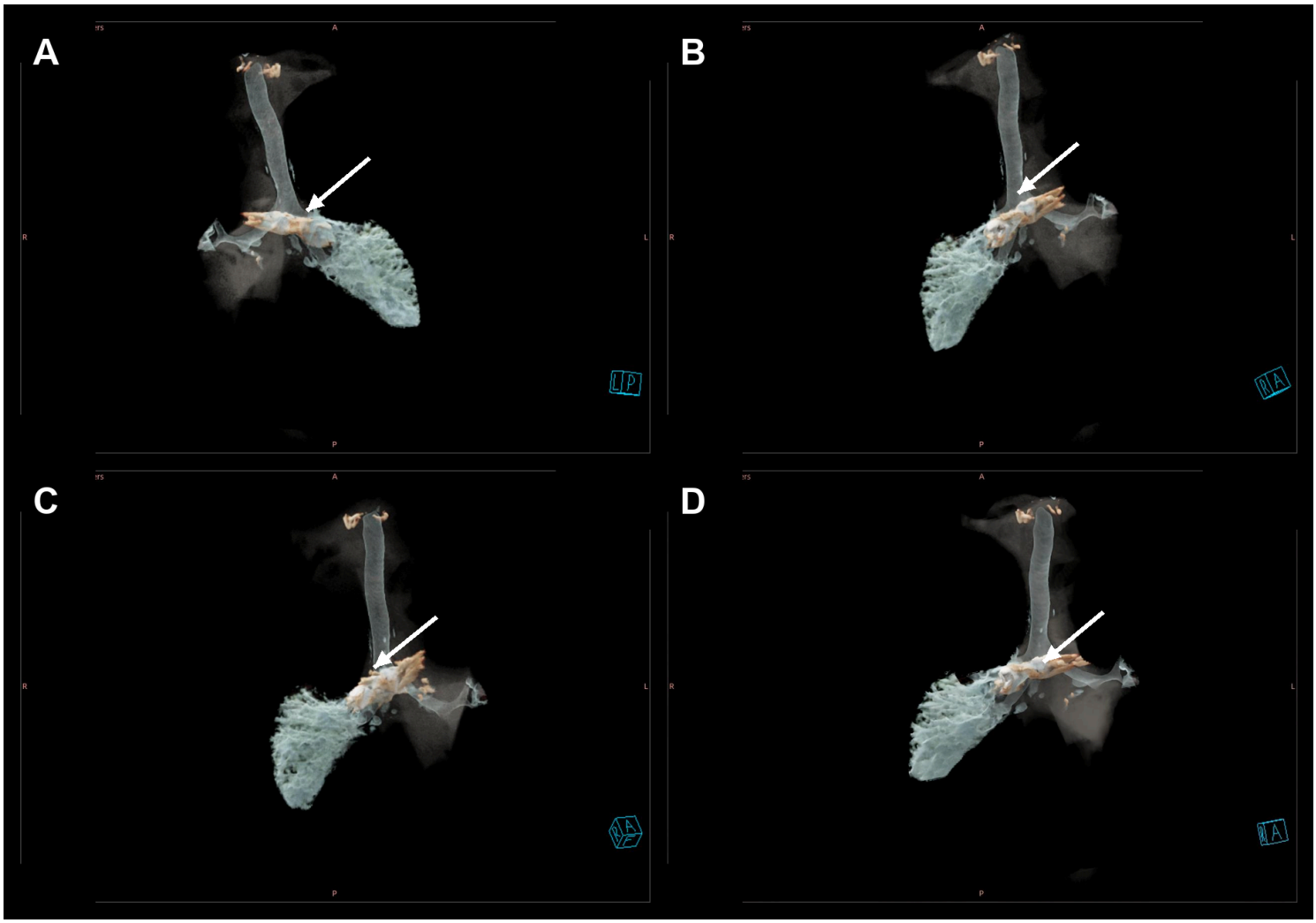


Figure 2

Three-dimensional volume-rendered computed tomography reconstruction (A–D, rotational views). The tracheobronchial tree and the retained metallic fragments (arrows) embedded at the tracheal carina are shown in their spatial relationship to the great vessels; the reconstruction was generated postoperatively (20 September 2026) from the preoperative contrast-enhanced CT dataset for illustrative purposes and was not used for intraoperative decision-making. All patient identifiers were removed from the images.

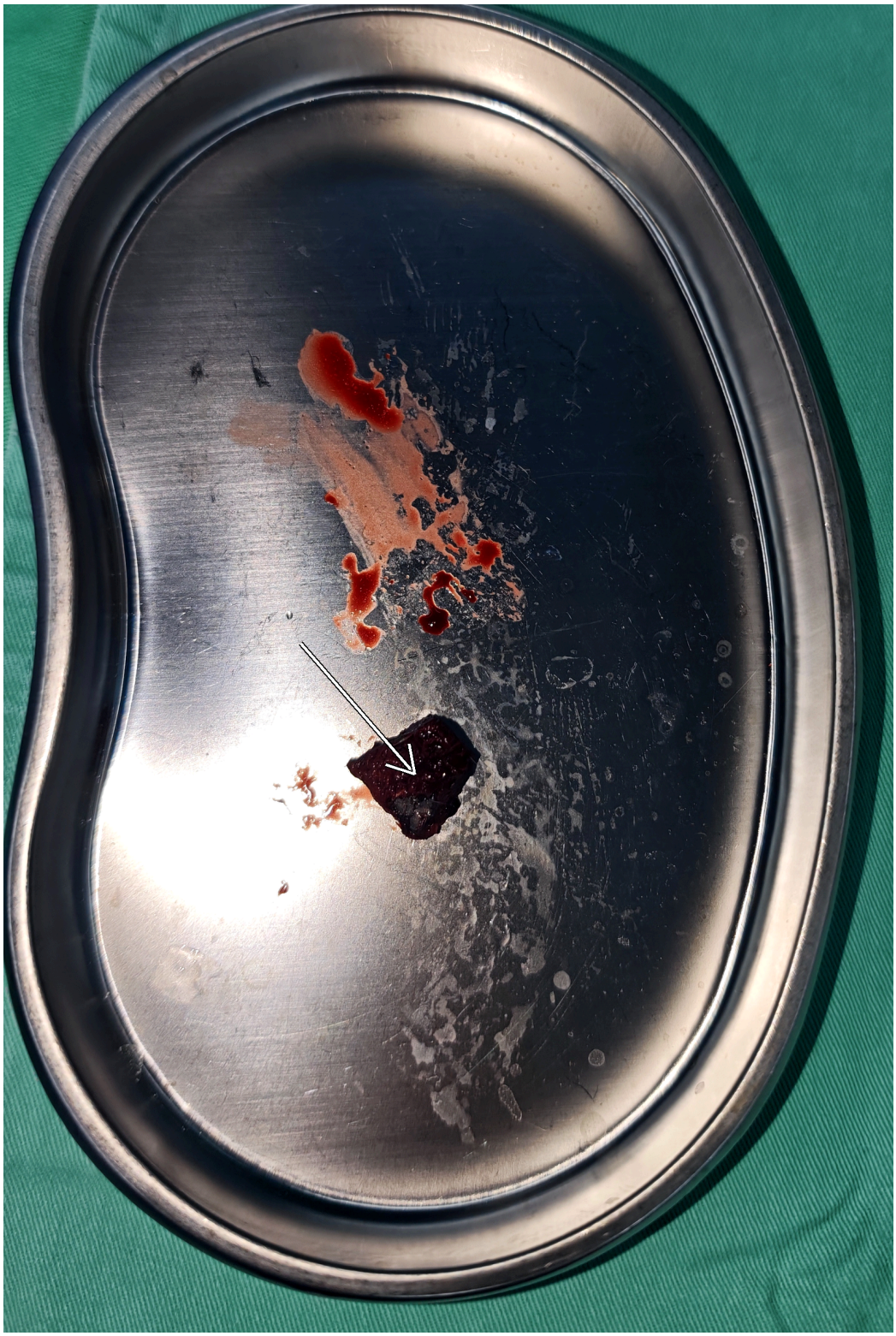


Figure 3

Photograph of one of the two extracted metallic fragments (arrow) in a stainless-steel kidney basin immediately after removal. The fragment is irregular and sharp-edged, consistent with a shattered metal grinding-wheel fragment.

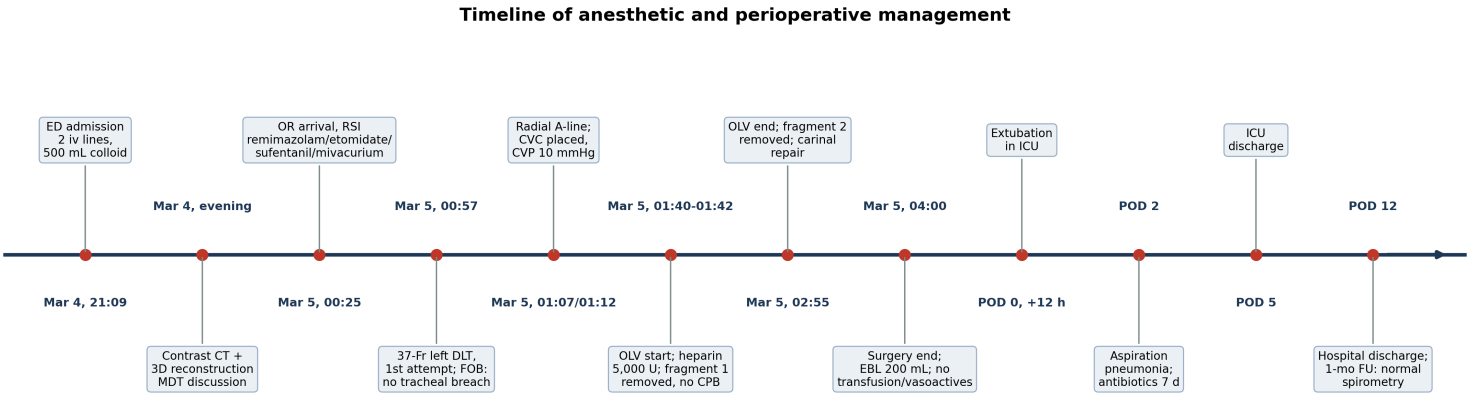


Figure 4

Schematic timeline of anesthetic and perioperative management (non-linear time scale), showing induction, airway management, invasive monitoring, the one-lung ventilation window, the sequential removal of both fragments, and the postoperative course.

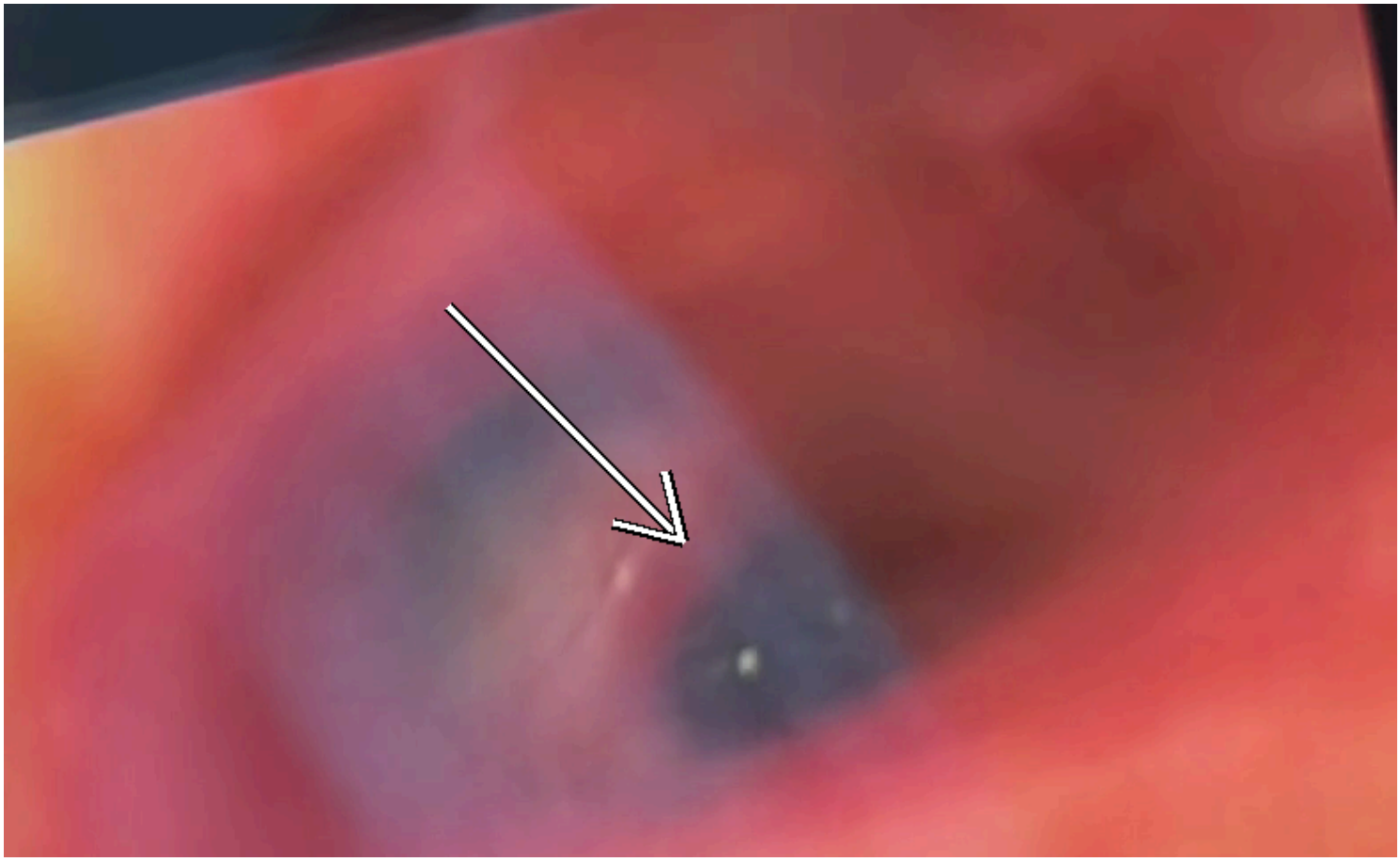


Figure 5

Intraoperative fiberoptic bronchoscopy still frame (full video provided as Additional file 2). View from the tracheal lumen at the carina after placement of the left-sided double-lumen tube: the blue bronchial cuff (arrow) is seated in the left mainstem bronchus without herniation above the carina; the carinal mucosa is intact, with no laceration, active bleeding, or false passage.